Practice Lab: CNN for CIFAR10

Training cifar10 Dataset with a CNN model (using tensorflow)

Outline

1 - Packages

In [53]:

```
import numpy as np
import pandas as pd
import tensorflow as tf
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Conv2D, MaxPool2D, Flatten,BatchNormalizatio
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras import layers, models
from sklearn.metrics import confusion_matrix , classification_report
from keras.layers import AveragePooling2D
from keras.layers import GlobalMaxPooling2D
from keras.layers import GlobalAveragePooling2D
from tensorflow.keras.utils import to_categorical
import seaborn as sns
from keras.utils import plot_model
```

2 - Loading Data

In [3]:

```
(x_train, y_train), (x_test, y_test) = tf.keras.datasets.cifar10.load_data()
```

Dataset overview

The CIFAR-10 dataset consists of 60000 32x32 colour images in 10 classes, with 6000 images per class. There are 50000 training images and 10000 test images.

The dataset is divided into five training batches and one test batch, each with 10000 images. The test batch contains exactly 1000 randomly-selected images from each class. The training batches contain the remaining images in random order, but some training batches may contain more images from one class than another. Between them, the training batches contain exactly 5000 images from each class.

In [3]:
```
x_train[0].shape
```
Out[3]:
```
(32, 32, 3)
```

In [4]:
```
y_train.size
```
Out[4]:
```
50000
```

In [5]:
```
x_train.size
```
Out[5]:
```
153600000
```

In [6]:
```
np.unique(y_train)
```
Out[6]:
```
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9], dtype=uint8)
```

In [37]:
```
labels = ["airplane"
,"automobile"
, "bird"
, "cat"
,"deer"
,"dog"
,"frog"
,"horse"
,"ship"
,"truck"]
```

Plotting

In [8]:
```
plt.imshow(x_train[12])
print(labels[int(y_train[12])])
```
```
horse
```

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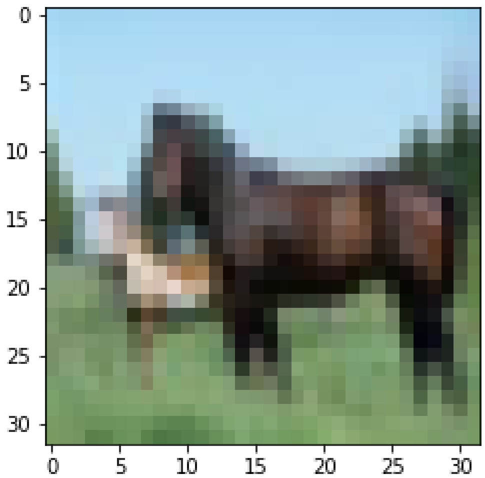

In [38]:
```
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
X = x_train
fig, axes = plt.subplots(5,5, figsize=(10,10))
fig.tight_layout(pad=0.1)

for i,ax in enumerate(axes.flat):
    random_index = np.random.randint(50000)
    ax.imshow(X[random_index], cmap='gray')
    ax.set_title(labels[int(y_train[random_index])])
    ax.set_axis_off()
```

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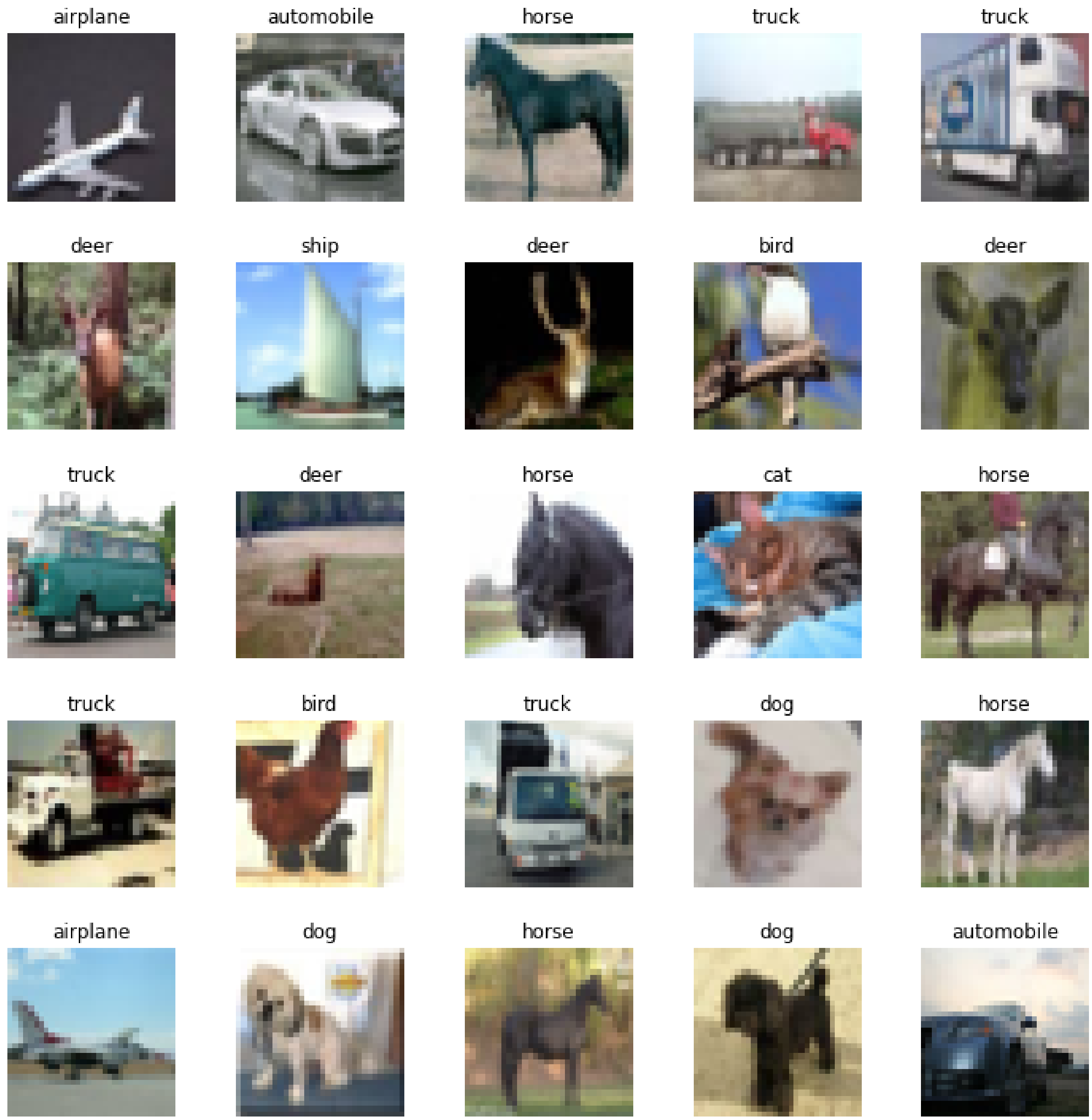

3 - Modeling

First we should Normalize our date

In [4]:
```
x_train = x_train / 255.0
x_test  = x_test  / 255.0
```

In [2]:
```
#Classification report
```

Define classificationReport method :

Precision

Is the ability of a classifier not to label an instance positive that is actually negative. For each class it is defined as the ratio of true positives to the sum of true and false positives.

Recall

The ability of a classifier to correctly find all positive instances. For each class, it is defined as the ratio of true positives to the sum of true positives and false negatives.

F1-score

The F1 score is a weighted harmonic mean of precision and recall such that the best score is 1.0 and the worst is 0.0.

In [5]:

```
def ClassificationReport(model):
    y_pred = model.predict(x_test)
    y_pred_classes = [np.argmax(element) for element in y_pred]
    print("Classification Report: \n", classification_report(y_test, y_pred_classes))
```

3.1 - simple MLP model :

In [15]:

```
mlp = models.Sequential([
        layers.Flatten(input_shape=(32,32,3)),
        layers.Dense(2048, activation='relu'),
        layers.Dense(1024, activation='relu'),
        layers.Dense(10, activation='softmax')
    ])

mlp.compile(optimizer='SGD',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])

mlp.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 45s 28ms/step - loss: 1.8193 - accuracy: 0.
3528
Epoch 2/5
1563/1563 [==============================] - 48s 31ms/step - loss: 1.6319 - accuracy: 0.
4241
Epoch 3/5
1563/1563 [==============================] - 51s 33ms/step - loss: 1.5473 - accuracy: 0.
4541
Epoch 4/5
1563/1563 [==============================] - 47s 30ms/step - loss: 1.4916 - accuracy: 0.
4750
```

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```
1563/1563 [==============================] - 48s 31ms/step - loss: 1.4398 - accuracy: 0.
4910
```

Out[15]:

```
<keras.callbacks.History at 0x210f022a9d0>
```

In [19]:

```
#Evaluating the MLP model
```

In [16]:

```
mlp.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 3s 10ms/step - loss: 1.4760 - accuracy: 0.464
3
```

Out[16]:

```
[1.4760462045669556, 0.4643000066280365]
```

In [34]:

```
ClassificationReport(mlp)
```

```
313/313 [==============================] - 2s 6ms/step
Classification Report:
              precision    recall  f1-score   support

           0       0.58      0.53      0.55      1000
           1       0.41      0.82      0.54      1000
           2       0.29      0.50      0.37      1000
           3       0.44      0.23      0.30      1000
           4       0.43      0.31      0.36      1000
           5       0.44      0.35      0.39      1000
           6       0.51      0.55      0.53      1000
           7       0.62      0.45      0.52      1000
           8       0.58      0.65      0.61      1000
           9       0.66      0.26      0.37      1000

    accuracy                           0.46     10000
   macro avg       0.49      0.46      0.45     10000
weighted avg       0.49      0.46      0.45     10000
```

Now we use CNN model

3.2 - CNN

In [26]:

```
cnn = Sequential([
    layers.Conv2D(filters=32, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu'),
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [27]:

```
cnn.compile(optimizer='adam',
              ...al_crossentropy',
```

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```
              metrics=['accuracy'])
cnn.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 24s 15ms/step - loss: 1.4031 - accuracy: 0.
4982
Epoch 2/5
1563/1563 [==============================] - 27s 17ms/step - loss: 1.0560 - accuracy: 0.
6318
Epoch 3/5
1563/1563 [==============================] - 27s 17ms/step - loss: 0.9153 - accuracy: 0.
6818
Epoch 4/5
1563/1563 [==============================] - 26s 17ms/step - loss: 0.8116 - accuracy: 0.
7183
Epoch 5/5
1563/1563 [==============================] - 26s 17ms/step - loss: 0.7234 - accuracy: 0.
7449
```

Out[27]:
```
<keras.callbacks.History at 0x2110a34dfd0>
```

In [28]:
```
cnn.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 2s 5ms/step - loss: 0.9776 - accuracy: 0.6693
```

Out[28]:
```
[0.9776250123977661, 0.6693000197410583]
```

In [39]:
```
cnn.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 30, 30, 32)        896

 max_pooling2d (MaxPooling2D  (None, 15, 15, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 13, 13, 64)        18496

 max_pooling2d_1 (MaxPooling  (None, 6, 6, 64)         0
 2D)

 flatten_3 (Flatten)         (None, 2304)              0

 dense_9 (Dense)             (None, 128)               295040

 dense_10 (Dense)            (None, 10)                1290

=================================================================
Total params: 315,722
Trainable params: 315,722
Non-trainable params: 0
_________________________________________________________________
```

In [30]:
```
cnn64 = Sequential([
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
```

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```
    layers.MaxPooling2D((2, 2)),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu'),
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [38]:

```
cnn64.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 43s 28ms/step - loss: 1.4424 - accuracy: 0.
4808
Epoch 2/5
1563/1563 [==============================] - 48s 31ms/step - loss: 1.0780 - accuracy: 0.
6230
Epoch 3/5
1563/1563 [==============================] - 46s 29ms/step - loss: 0.9444 - accuracy: 0.
6707
Epoch 4/5
1563/1563 [==============================] - 47s 30ms/step - loss: 0.8539 - accuracy: 0.
6999
Epoch 5/5
1563/1563 [==============================] - 47s 30ms/step - loss: 0.7867 - accuracy: 0.
7256
```

Out[38]:

```
<keras.callbacks.History at 0x2110cffc6d0>
```

In [40]:

```
cnn64.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 3s 9ms/step - loss: 0.9197 - accuracy: 0.6845
```

Out[40]:

```
[0.9196601510047913, 0.684499979019165]
```

In [41]:

```
ClassificationReport(cnn64)
```

```
313/313 [==============================] - 3s 9ms/step
Classification Report:
              precision    recall  f1-score   support

           0       0.73      0.71      0.72      1000
           1       0.82      0.80      0.81      1000
           2       0.64      0.50      0.56      1000
           3       0.55      0.47      0.51      1000
           4       0.65      0.56      0.60      1000
           5       0.58      0.59      0.58      1000
           6       0.69      0.81      0.74      1000
           7       0.71      0.73      0.72      1000
           8       0.79      0.82      0.80      1000
           9       0.66      0.85      0.74      1000

    accuracy                           0.68     10000
   macro avg       0.68      0.68      0.68     10000
```

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```
weighted avg       0.68      0.68      0.68     10000
```

In [48]:

```
cnn32 = Sequential([
    layers.Conv2D(filters=32, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu'),
    layers.MaxPooling2D((2, 2)),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu'),
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [49]:

```
cnn32.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn32.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 26s 16ms/step - loss: 1.5680 - accuracy: 0.
4231
Epoch 2/5
1563/1563 [==============================] - 31s 20ms/step - loss: 1.2152 - accuracy: 0.
5671
Epoch 3/5
1563/1563 [==============================] - 31s 20ms/step - loss: 1.0814 - accuracy: 0.
6172
Epoch 4/5
1563/1563 [==============================] - 29s 19ms/step - loss: 0.9920 - accuracy: 0.
6534
Epoch 5/5
1563/1563 [==============================] - 29s 18ms/step - loss: 0.9175 - accuracy: 0.
6798
```

Out[49]:

```
<keras.callbacks.History at 0x21108487190>
```

Types of Pooling Layers

In [75]:

```
#Max pooling (32)
```

Max pooling is a pooling operation that selects the maximum element from the region of the feature map covered by the filter. Thus, the output after max-pooling layer would be a feature map containing the most prominent features of the previous feature map.

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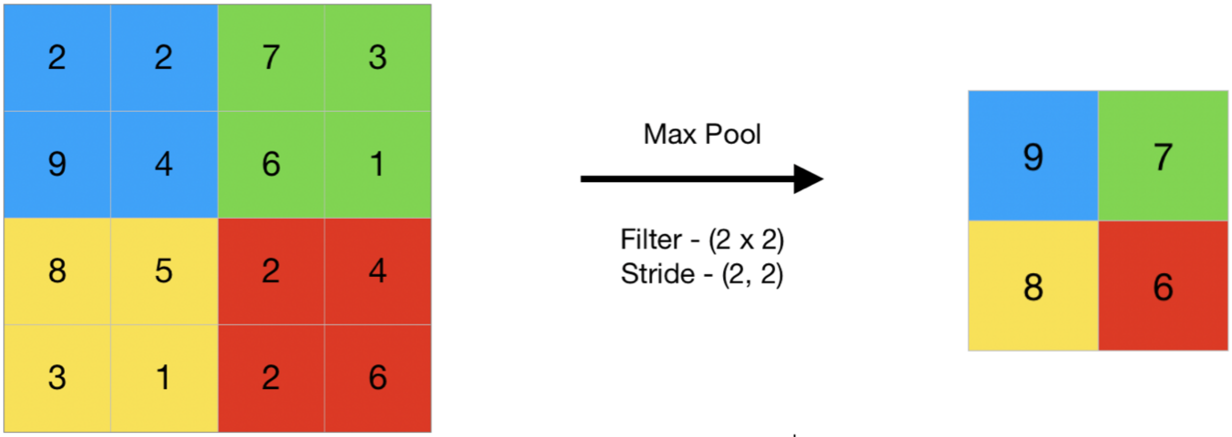

In [76]:
```
cnn_MaxPooling32 = Sequential([
    layers.Conv2D(filters=32, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [77]:
```
cnn_MaxPooling32.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn_MaxPooling32.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 18s 11ms/step - loss: 1.4437 - accuracy: 0.
4859
Epoch 2/5
1563/1563 [==============================] - 20s 13ms/step - loss: 1.1487 - accuracy: 0.
5963
Epoch 3/5
1563/1563 [==============================] - 20s 13ms/step - loss: 1.0188 - accuracy: 0.
6433
Epoch 4/5
1563/1563 [==============================] - 20s 13ms/step - loss: 0.9241 - accuracy: 0.
6765
Epoch 5/5
1563/1563 [==============================] - 20s 13ms/step - loss: 0.8518 - accuracy: 0.
7027
```

Out[77]:
```
<keras.callbacks.History at 0x211371d2df0>
```

accuracy: 0.7027

In [78]:
```
#Max pooling (64)
```

In [79]:
```
cnn_MaxPooling64 = Sequential([
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
```

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```
    layers.Dense(10, activation='softmax')
])
```

I use a bigger epoch number for this model because it was too close to average pooling

In [100…

```
cnn_MaxPooling64.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn_MaxPooling64.fit(x_train, y_train, epochs=20)
```

```
Epoch 1/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0662 - accuracy: 0.
9780
Epoch 2/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0594 - accuracy: 0.
9801
Epoch 3/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0585 - accuracy: 0.
9817
Epoch 4/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0549 - accuracy: 0.
9824
Epoch 5/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0588 - accuracy: 0.
9812
Epoch 6/20
1563/1563 [==============================] - 37s 24ms/step - loss: 0.0580 - accuracy: 0.
9817
Epoch 7/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0614 - accuracy: 0.
9810
Epoch 8/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0563 - accuracy: 0.
9824
Epoch 9/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0490 - accuracy: 0.
9842
Epoch 10/20
1563/1563 [==============================] - 37s 23ms/step - loss: 0.0460 - accuracy: 0.
9849
Epoch 11/20
1563/1563 [==============================] - 38s 24ms/step - loss: 0.0570 - accuracy: 0.
9823
Epoch 12/20
1563/1563 [==============================] - 37s 24ms/step - loss: 0.0515 - accuracy: 0.
9836
Epoch 13/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0426 - accuracy: 0.
9872
Epoch 14/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0555 - accuracy: 0.
9834
Epoch 15/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0439 - accuracy: 0.
9867
Epoch 16/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0482 - accuracy: 0.
```

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```
Epoch 17/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0454 - accuracy: 0.
9859
Epoch 18/20
1563/1563 [==============================] - 37s 24ms/step - loss: 0.0516 - accuracy: 0.
9841
Epoch 19/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0350 - accuracy: 0.
9893
Epoch 20/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0512 - accuracy: 0.
9842
```

Out[100…

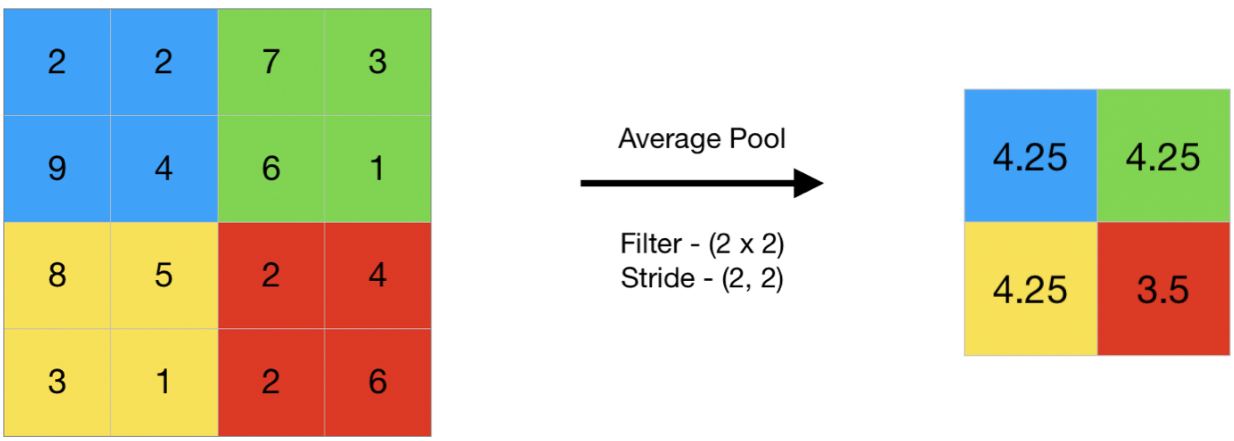
```
<keras.callbacks.History at 0x21111bde850>
```

loss: 0.0512 - accuracy: 0.9842

In [72]:

```python
#Average pooling
```

Average pooling computes the average of the elements present in the region of feature map covered by the filter. Thus, while max pooling gives the most prominent feature in a particular patch of the feature map, average pooling gives the average of features present in a patch.



In [81]:

```python
cnn_AveragePooling = Sequential([
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    AveragePooling2D(pool_size = 2, strides = 2),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [101…

```python
cnn_AveragePooling.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn_AveragePooling.fit(x_train, y_train, epochs=20)
```

```
Epoch 1/20
1563/1563 [==============================] - 32s 20ms/step - loss: 0.0583 - accuracy: 0.
9804
Epoch 2/20
====] - 34s 22ms/step - loss: 0.0597 - accuracy: 0.
9809
```

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```
Epoch 3/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0576 - accuracy: 0.
9825
Epoch 4/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0499 - accuracy: 0.
9841
Epoch 5/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0516 - accuracy: 0.
9838
Epoch 6/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0558 - accuracy: 0.
9827
Epoch 7/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0501 - accuracy: 0.
9848
Epoch 8/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0472 - accuracy: 0.
9856
Epoch 9/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0437 - accuracy: 0.
9866
Epoch 10/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0516 - accuracy: 0.
9841
Epoch 11/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0447 - accuracy: 0.
9865
Epoch 12/20
1563/1563 [==============================] - 35s 22ms/step - loss: 0.0494 - accuracy: 0.
9849
Epoch 13/20
1563/1563 [==============================] - 38s 24ms/step - loss: 0.0412 - accuracy: 0.
9873
Epoch 14/20
1563/1563 [==============================] - 39s 25ms/step - loss: 0.0477 - accuracy: 0.
9853
Epoch 15/20
1563/1563 [==============================] - 36s 23ms/step - loss: 0.0392 - accuracy: 0.
9877
Epoch 16/20
1563/1563 [==============================] - 34s 22ms/step - loss: 0.0467 - accuracy: 0.
9855
Epoch 17/20
1563/1563 [==============================] - 39s 25ms/step - loss: 0.0439 - accuracy: 0.
9875
Epoch 18/20
1563/1563 [==============================] - 39s 25ms/step - loss: 0.0412 - accuracy: 0.
9876
Epoch 19/20
1563/1563 [==============================] - 39s 25ms/step - loss: 0.0395 - accuracy: 0.
9881
Epoch 20/20
1563/1563 [==============================] - 33s 21ms/step - loss: 0.0327 - accuracy: 0.
9903
```

Out[101…

```
<keras.callbacks.History at 0x21136e45460>
```

loss: 0.0327 - accuracy: 0.9903

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In [73]:

```
#Global pooling
```

Global pooling reduces each channel in the feature map to a single value. Thus, an nh x nw x nc feature map is reduced to 1 x 1 x nc feature map. This is equivalent to using a filter of dimensions nh x nw i.e. the dimensions of the feature map.

In [178…

```
cnn_GlobalPooling = Sequential([
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.GlobalAveragePooling2D(),
    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [179…

```
cnn_GlobalPooling.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn_GlobalPooling.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1563/1563 [==============================] - 15s 10ms/step - loss: 2.0315 - accuracy: 0.
2330
Epoch 2/5
1563/1563 [==============================] - 17s 11ms/step - loss: 1.7967 - accuracy: 0.
3192
Epoch 3/5
1563/1563 [==============================] - 20s 13ms/step - loss: 1.7135 - accuracy: 0.
3510
Epoch 4/5
1563/1563 [==============================] - 21s 13ms/step - loss: 1.6892 - accuracy: 0.
3646
Epoch 5/5
1563/1563 [==============================] - 18s 12ms/step - loss: 1.6691 - accuracy: 0.
3740
```

Out[179…

```
<keras.callbacks.History at 0x2112101b0a0>
```

accuracy: 0.3740

In [102…

```
cnn_AveragePooling.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 2s 6ms/step - loss: 4.3350 - accuracy: 0.6109
```

Out[102…

```
[4.334970951080322, 0.6108999848365784]
```

In [103…

```
cnn_MaxPooling64.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 2s 6ms/step - loss: 4.2818 - accuracy: 0.6206
```

Out[103…

```
[4.2817840576171875, 0.6205999851226807]
```

In [114…

```
#Let's combine these for the best result
```

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```
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    BatchNormalization(),
    AveragePooling2D(pool_size = 2, strides = 2),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(512,activation='relu'),
    layers.Dense(10, activation='softmax')
])
```

In [7]:

```
cnn_Final.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
cnn_Final.fit(x_train, y_train, epochs=15)
```

```
Epoch 1/15
1563/1563 [==============================] - 63s 40ms/step - loss: 1.2560 - accuracy: 0.
5557
Epoch 2/15
1563/1563 [==============================] - 59s 38ms/step - loss: 0.8956 - accuracy: 0.
6872
Epoch 3/15
1563/1563 [==============================] - 62s 39ms/step - loss: 0.6932 - accuracy: 0.
7587
Epoch 4/15
1563/1563 [==============================] - 64s 41ms/step - loss: 0.5263 - accuracy: 0.
8137
Epoch 5/15
1563/1563 [==============================] - 65s 41ms/step - loss: 0.3675 - accuracy: 0.
8719
Epoch 6/15
1563/1563 [==============================] - 65s 41ms/step - loss: 0.2514 - accuracy: 0.
9128
Epoch 7/15
1563/1563 [==============================] - 65s 41ms/step - loss: 0.1922 - accuracy: 0.
9323
Epoch 8/15
1563/1563 [==============================] - 67s 43ms/step - loss: 0.1448 - accuracy: 0.
9492
Epoch 9/15
1563/1563 [==============================] - 63s 40ms/step - loss: 0.1282 - accuracy: 0.
9571
Epoch 10/15
1563/1563 [==============================] - 64s 41ms/step - loss: 0.1182 - accuracy: 0.
9610
Epoch 11/15
1563/1563 [==============================] - 65s 42ms/step - loss: 0.1042 - accuracy: 0.
9659
Epoch 12/15
1563/1563 [==============================] - 64s 41ms/step - loss: 0.0903 - accuracy: 0.
9704
Epoch 13/15
1563/1563 [==============================] - 61s 39ms/step - loss: 0.0918 - accuracy: 0.
9708
Epoch 14/15
1563/1563 [==============================] - 59s 38ms/step - loss: 0.0771 - accuracy: 0.
9740
```

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```
1563/1563 [==============================] - 57s 36ms/step - loss: 0.0868 - accuracy: 0.
9724
```

Out[7]:
```
<keras.callbacks.History at 0x1a418071e20>
```

In [115…
```
#First try
```

In [111…
```
cnn_Final.summary()
```

```
Model: "sequential_29"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_47 (Conv2D)          (None, 30, 30, 64)        1792      
                                                                 
 average_pooling2d_8 (Averag  (None, 15, 15, 64)       0         
 ePooling2D)                                                     
                                                                 
 conv2d_48 (Conv2D)          (None, 13, 13, 64)        36928     
                                                                 
 max_pooling2d_32 (MaxPoolin  (None, 6, 6, 64)         0         
 g2D)                                                            
                                                                 
 flatten_27 (Flatten)        (None, 2304)              0         
                                                                 
 dense_66 (Dense)            (None, 128)               295040    
                                                                 
 batch_normalization (BatchN  (None, 128)              512       
 ormalization)                                                   
                                                                 
 dense_67 (Dense)            (None, 10)                1290      
                                                                 
=================================================================
Total params: 335,562
Trainable params: 335,306
Non-trainable params: 256
_________________________________________________________________
```

loss: 0.4474 - accuracy: 0.8409

In [116…
```
#Second try
```

In [117…
```
cnn_Final.summary()
```

```
Model: "sequential_30"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_49 (Conv2D)          (None, 30, 30, 64)        1792      
                                                                 
 average_pooling2d_9 (Averag  (None, 15, 15, 64)       0         
 ePooling2D)                                                     
                                                                 
 conv2d_50 (Conv2D)          (None, 13, 13, 64)        36928     
                                                                 
 max_pooling2d_33 (MaxPoolin  (None, 6, 6, 64)         0         
```

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```
 g2D)

 flatten_28 (Flatten)        (None, 2304)              0

 dense_68 (Dense)            (None, 256)               590080

 dense_69 (Dense)            (None, 10)                2570

=================================================================
Total params: 631,370
Trainable params: 631,370
Non-trainable params: 0
_________________________________________________________________
```

loss: 0.1076 - accuracy: 0.9618

In [127…

```
#Third Try
```

In [126…

```
cnn_Final.summary()
```

```
Model: "sequential_32"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_57 (Conv2D)          (None, 30, 30, 64)        1792

 average_pooling2d_13 (Avera  (None, 15, 15, 64)       0
 gePooling2D)

 conv2d_58 (Conv2D)          (None, 13, 13, 64)        36928

 max_pooling2d_37 (MaxPoolin  (None, 6, 6, 64)         0
 g2D)

 flatten_32 (Flatten)        (None, 2304)              0

 dense_75 (Dense)            (None, 256)               590080

 dense_76 (Dense)            (None, 128)               32896

 dense_77 (Dense)            (None, 10)                1290

=================================================================
Total params: 662,986
Trainable params: 662,986
Non-trainable params: 0
_________________________________________________________________
```

loss: 0.1673 - accuracy: 0.9415

In [128…

```
# 4th try
```

In [131…

```
cnn_Final.summary()
```

```
Model: "sequential_33"
_________________________________________________________________
```

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```
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_59 (Conv2D)          (None, 30, 30, 64)        1792      
                                                                 
 average_pooling2d_14 (Avera  (None, 15, 15, 64)       0         
 gePooling2D)                                                    
                                                                 
 conv2d_60 (Conv2D)          (None, 13, 13, 64)        36928     
                                                                 
 max_pooling2d_38 (MaxPoolin  (None, 6, 6, 64)         0         
 g2D)                                                            
                                                                 
 flatten_33 (Flatten)        (None, 2304)              0         
                                                                 
 dense_78 (Dense)            (None, 512)               1180160   
                                                                 
 dense_79 (Dense)            (None, 10)                5130      
                                                                 
=================================================================
Total params: 1,224,010
Trainable params: 1,224,010
Non-trainable params: 0
_________________________________________________________________
```

loss: 0.0787 - accuracy: 0.9730

In [136…

```python
# 5th try
```

In [137…

```python
cnn_Final.summary()
```

```
Model: "sequential_35"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_63 (Conv2D)          (None, 30, 30, 64)        1792      
                                                                 
 average_pooling2d_16 (Avera  (None, 15, 15, 64)       0         
 gePooling2D)                                                    
                                                                 
 conv2d_64 (Conv2D)          (None, 13, 13, 64)        36928     
                                                                 
 max_pooling2d_40 (MaxPoolin  (None, 6, 6, 64)         0         
 g2D)                                                            
                                                                 
 flatten_35 (Flatten)        (None, 2304)              0         
                                                                 
 dense_83 (Dense)            (None, 1024)              2360320   
                                                                 
 batch_normalization_1 (Batc  (None, 1024)             4096      
 hNormalization)                                                 
                                                                 
 dense_84 (Dense)            (None, 512)               524800    
                                                                 
 dense_85 (Dense)            (None, 10)                5130      
                                                                 
=================================================================
Trainable params: 2,931,018
```

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```
Non-trainable params: 2,048
_________________________________________________________________
```

loss: 0.2206 - accuracy: 0.9224

In [14]:
```
#Final try
```

In [15]:
```
cnn_Final.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_2 (Conv2D)           (None, 30, 30, 64)        1792

 batch_normalization_1 (Batc  (None, 30, 30, 64)       256
 hNormalization)

 average_pooling2d_1 (Averag  (None, 15, 15, 64)       0
 ePooling2D)

 conv2d_3 (Conv2D)           (None, 13, 13, 64)        36928

 max_pooling2d_1 (MaxPooling  (None, 6, 6, 64)         0
 2D)

 flatten_1 (Flatten)         (None, 2304)              0

 dense_2 (Dense)             (None, 512)               1180160

 dropout (Dropout)           (None, 512)               0

 dense_3 (Dense)             (None, 10)                5130

=================================================================
Total params: 1,224,266
Trainable params: 1,224,138
Non-trainable params: 128
_________________________________________________________________
```

4 - Let's evaluate our model

In [9]:
```
cnn_Final.evaluate(x_test,y_test)
```

```
313/313 [==============================] - 5s 15ms/step - loss: 2.2765 - accuracy: 0.683
9
```

Out[9]:
```
[2.2765324115753174, 0.683899998664856]
```

loss: 2.2765 - accuracy: 0.6839

In [10]:
```
ClassificationReport(cnn_Final)
```

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```
313/313 [==============================] - 6s 18ms/step
Classification Report:
              precision    recall  f1-score   support

           0       0.74      0.73      0.74      1000
           1       0.84      0.80      0.82      1000
           2       0.57      0.57      0.57      1000
           3       0.46      0.52      0.48      1000
           4       0.69      0.57      0.62      1000
           5       0.57      0.56      0.57      1000
           6       0.70      0.81      0.75      1000
           7       0.76      0.70      0.73      1000
           8       0.77      0.83      0.80      1000
           9       0.78      0.75      0.77      1000

    accuracy                           0.68     10000
   macro avg       0.69      0.68      0.68     10000
weighted avg       0.69      0.68      0.68     10000
```

As you can see we got a big loss number for testing data

Now we prevent overfitting for our model

In [23]:

```
cnn_Final = Sequential([
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    BatchNormalization(),
    AveragePooling2D(pool_size = 2, strides = 2),
    layers.Conv2D(filters=64, kernel_size=(3, 3), activation='relu', input_shape=(32, 3
    layers.MaxPooling2D((2, 2)),
    layers.Flatten(),
    layers.Dense(512,activation='relu'),
    Dropout(0.5),
    layers.Dense(10, activation='softmax')
])
```

In [24]:

```
cnn_Final.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
```

In [25]:

```
history = cnn_Final.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=7, b
```

```
Epoch 1/7
167/167 [==============================] - 48s 284ms/step - loss: 1.6067 - accuracy: 0.4
260 - val_loss: 2.2226 - val_accuracy: 0.3002
Epoch 2/7
167/167 [==============================] - 48s 287ms/step - loss: 1.2128 - accuracy: 0.5
703 - val_loss: 2.1073 - val_accuracy: 0.4955
Epoch 3/7
167/167 [==============================] - 49s 291ms/step - loss: 1.0481 - accuracy: 0.6
322 - val_loss: 1.3993 - val_accuracy: 0.6226
Epoch 4/7
167/167 [==============================] - 49s 291ms/step - loss: 0.9406 - accuracy: 0.6
712 - val_loss: 0.9649 - val_accuracy: 0.6710
Epoch 5/7
Loading [MathJax]/jax/output/CommonHTML/fonts/TeX/fontdata.js ==] - 49s 290ms/step - loss: 0.8643 - accuracy: 0.6
979 - val_loss: 0.9692 - val_accuracy: 0.6629
```

```
Epoch 6/7
167/167 [==============================] - 49s 295ms/step - loss: 0.7951 - accuracy: 0.7
228 - val_loss: 0.8960 - val_accuracy: 0.6911
Epoch 7/7
167/167 [==============================] - 49s 292ms/step - loss: 0.7357 - accuracy: 0.7
420 - val_loss: 0.9560 - val_accuracy: 0.6789
```

Try with binary cross entropy

In [19]:
```
y_categorical_train = to_categorical(y_train, 10)
y_categorical_test = to_categorical(y_test, 10)
```

In [26]:
```
cnn_Final.compile(loss="categorical_crossentropy", optimizer="adam", metrics=["accuracy
```

In [28]:
```
history = cnn_Final.fit(x_train, y_categorical_train, validation_data=(x_test, y_catego
```

```
Epoch 1/7
167/167 [==============================] - 48s 285ms/step - loss: 0.6871 - accuracy: 0.7
561 - val_loss: 0.8966 - val_accuracy: 0.6960
Epoch 2/7
167/167 [==============================] - 48s 289ms/step - loss: 0.6258 - accuracy: 0.7
788 - val_loss: 0.8495 - val_accuracy: 0.7120
Epoch 3/7
167/167 [==============================] - 48s 289ms/step - loss: 0.5705 - accuracy: 0.7
995 - val_loss: 0.8333 - val_accuracy: 0.7230
Epoch 4/7
167/167 [==============================] - 49s 291ms/step - loss: 0.5290 - accuracy: 0.8
132 - val_loss: 0.8315 - val_accuracy: 0.7213
Epoch 5/7
167/167 [==============================] - 50s 297ms/step - loss: 0.4872 - accuracy: 0.8
282 - val_loss: 0.8431 - val_accuracy: 0.7282
Epoch 6/7
167/167 [==============================] - 50s 297ms/step - loss: 0.4408 - accuracy: 0.8
435 - val_loss: 0.8508 - val_accuracy: 0.7348
Epoch 7/7
167/167 [==============================] - 51s 304ms/step - loss: 0.4071 - accuracy: 0.8
548 - val_loss: 0.9347 - val_accuracy: 0.7089
```

In [29]:
```
Y_prediction = cnn_Final.predict(x_test)
```

```
313/313 [==============================] - 4s 11ms/step
```

In [30]:
```
Y_prediction.shape
```

Out[30]:
```
(10000, 10)
```

In [31]:
```
Y_prediction
```

Out[31]:
```
array([[2.23211202e-04, 5.51889316e-05, 1.63338453e-04, ...,
        8.09079211e-05, 7.35946838e-03, 4.46087643e-06],
       [7.68834725e-03, 3.08940606e-03, 9.68137073e-08, ...,
        2.80909296e-10, 9.89222050e-01, 6.19801526e-08],
Loading [MathJax]/jax/output/CommonHTML/fonts/TeX/fontdata.js 2, 8.07335135e-03, ...,
        7.33093423e-03, 6.00331280e-01, 1.98803213e-03],
```

```
        ...,
        [8.19458066e-08, 2.57242959e-07, 2.24625575e-04, ...,
         6.04846049e-03, 1.22072993e-06, 1.16995146e-07],
        [3.10936980e-02, 5.96647933e-02, 4.47810907e-03, ...,
         5.71781397e-03, 2.54460581e-04, 6.01701288e-07],
        [7.11552605e-12, 5.51200578e-13, 9.32100264e-08, ...,
         9.99882936e-01, 1.24371059e-14, 6.78344672e-11]], dtype=float32)
```

In [32]:

```
classes_x = np.argmax(Y_prediction, axis=1)
```

In [34]:

```
classes_x.shape
```

Out[34]:

```
(10000,)
```

In [65]:

```
warnings.simplefilter(action='ignore', category=FutureWarning)
X = x_test
fig, axes = plt.subplots(10,10, figsize=(20,20))
fig.tight_layout(pad=0.1)
print("Model Predict/Reality")
for i,ax in enumerate(axes.flat):
    random_index = np.random.randint(10000)
    ax.imshow(X[random_index], cmap='gray')
    ax.set_title(labels[int(classes_x[random_index])]+"/" +labels[int(y_test[random_ind
    ax.set_axis_off()
```

```
Model Predict/Reality
```

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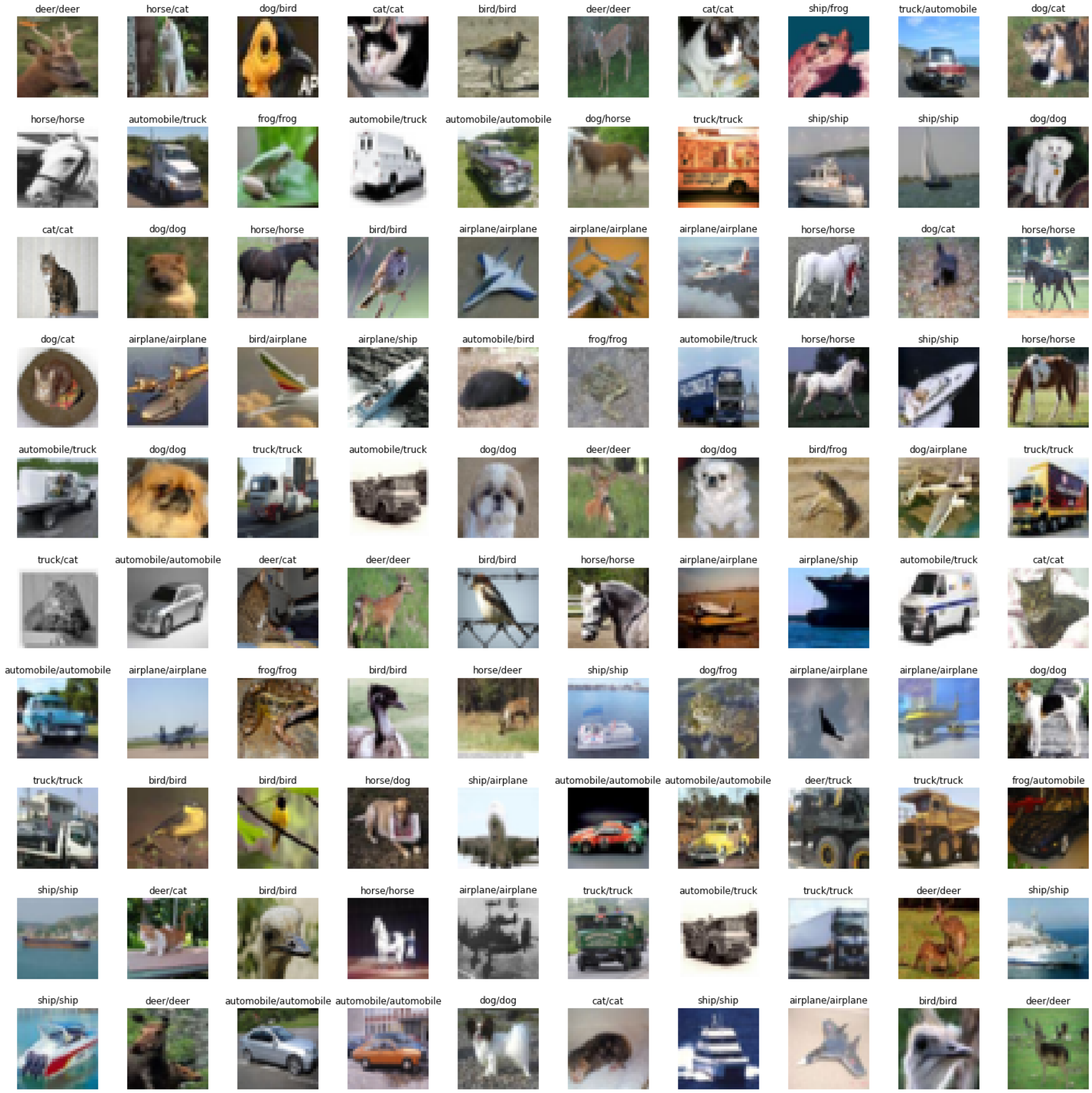

In [52]:

```
plt.figure(figsize=(20, 20))
sns.heatmap(confusion_matrix(y_test, classes_x), annot=True)
plt.show()
```

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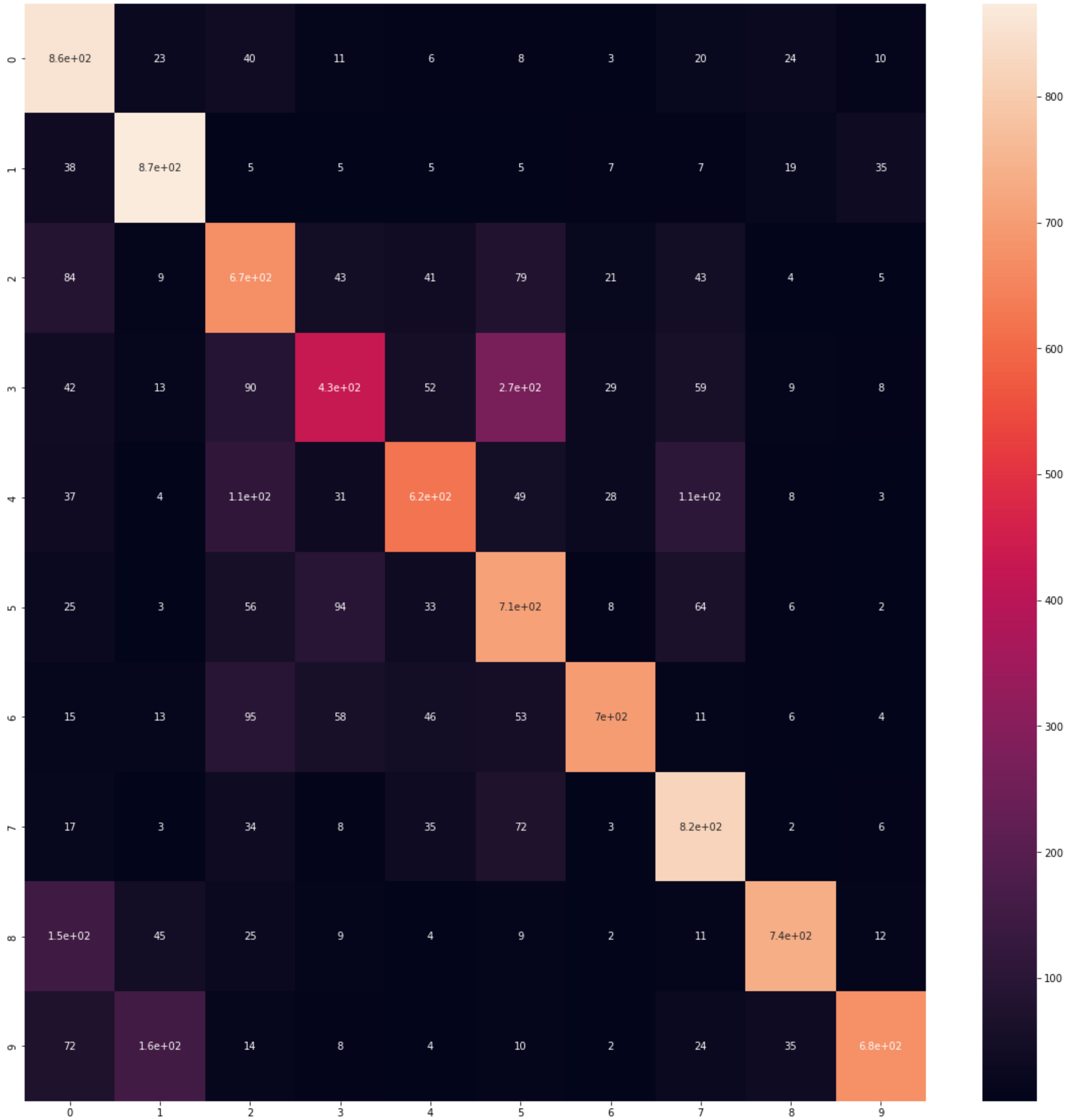

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